



The invention relates to a scanning converter for converting the scanning method for a television signal from an interlaced scanning method into a progressive scanning method and to a method therefor, and more particularly, to an interlaced-to-progressive scanning converter which improves the effects of eliminating noise and preventing picture quality deterioration by adopting a double-smoothing function using median-filtering, and to a method therefor.

In general, in an image signal processor such as those used in televisions, facsimiles or medical appliances, the image signal based on an interlaced scanning method is converted into a progressive scanning signal for improving picture quality, which is otherwise somewhat deteriorated by the use of interlaced scanning.

In the case of a television signal, the interlaced scanning method is used for an effective utilization of transmission bands and the physical properties of a television receiver may result in deterioration phenomena such as inter-line flickering or line crawling. Moreover, in the pursuit of large high-quality television screens, scanning lines are exposed on a screen along with such deterioration phenomena.

In order to alleviate the picture quality deterioration due to the interlaced scanning method as described above, the scanning method of a television signal is converted into a progressive scanning method.

In the early days, the interlaced-to-progressive scanning converter adopted the method of processing a signal on horizontal and vertical space plane. However, according to the recent pursuit of high picture quality for televisions and the reduction of memory cost in connection therewith, motion-adaptive signal processing is being generalized for producing televisions having high picture quality.

In the prior art system of Figure 1, an interlaced-to-progressive converter is shown, the converter performs a conversion by linear interpolation using a vertical median, delays the interlaced scanning signal input from a 1H delay 11 and applies the delayed signal to a first input terminal of a selector 14. Here, an adder 12 adds the input interlaced scanning signal to the 1H delayed signal and applies the resultant signal to a second input terminal of the selector 14 through a divider-by-two circuit 13. Then, selector 14 selectively outputs the 1H delayed signal or the divided-by-two signal alternately at a double speed of interlaced scanning, to thereby output a progressive scanning signal.

However, the interlaced-to-progressive scanning converter shown in Figure 1 may generate a blurriness in the displayed image.

Interlaced-to-progressive scanning converters which perform a conversion by three-dimensional interpolation using motion-adaptive signal processing, improve the resolution of motionless areas but cannot prevent a stepped edge which is a phenomenon resulting in picture contour deterioration. At this time, a separate motion detector must be attached and the hardware becomes complex due to the necessity for using a field memory, and the cost is increased accordingly.

Meanwhile, in the case of a transmitted image signal or a signal reproduced from a recorded image signal, picture quality is deteriorated due to the mixing of an impulse noise or Gaussian noise within a given channel. In this case, when performing motion-adaptive signal processing using motion detection, since an analog correlation which can be indicated as the level difference between a current frame and a previous frame is obtained and the extent of motion is calculated, pictures which include a noise signal may cause a malfunction during detection. Although the interlaced-to-progressive scanning conversion is performed, a deteriorated picture may be obtained due to the presence of noise.

Impulse noise on a picture signal may be generated by a low signal-to-noise ratio of an FM satellite broadcast signal or by an electromagnetic interference in the television receiver.

To solve the aforementioned problems, there has been proposed an interlaced-to-progressive scanning converting method in which a median filter having no motion detecting function but having an effective noise preventing function is adopted.

The interlaced-to-progressive scanning converting method using a median filter is disclosed in a paper by Licia Capodiferro entitled "Interlaced-to-progressive Conversion by Median-filtering" in *Proceedings of the 3rd International Workshop on HDTV* (Torino, Italy; September 1989). Here, the median filter takes a median value between adjacent data, and thus, the hardware implementation of such a converter is simple.

However, the interlaced-to-progressive scanning converting method using the median filter results in a stepped edge phenomenon which is more apparent than in the method using the motion-adaptive signal processing. Also, if noise is mixed on the channel, since the pixels of the noise components are used for an interpolation, the signal-to-noise ratio is lower than the case of the interlaced-to-progressive scanning converting method using a linear interpolation.

To compensate for such shortcomings, a finite impulse response (FIR) filter may be used together with the median filter for pre-processing the interlaced-to-progressive conversion. The FIR filter is effective in eliminating the Gaussian noise but is not effective in eliminating the impulse noise. On the other hand, the median filter is effective in eliminating the impulse noise but is not effective in eliminating the Gaussian noise. Accordingly, as shown in Figure 2, a double-smoothing method which is a combination of the median filter and FIR

filter has been proposed.

The double-smoothing method shown in Figure 2 is disclosed in a paper by L.R. Rabiner, M.R. Sambur and C.E. Schmidt entitled "Applications of a Non-linear Smoothing Algorithm for Speech Processing" in *IEEE Trans. on ASSP*, Vol.23 (December 1975), pp552-557.

In Figure 2, the impulse noise and Gaussian noise of the interlaced scanning signal  $x_k$  including noise components are filtered by the median filter 21 and the FIR filter 22. The input signal  $x_k$ , being delayed in a delay 23 for a predetermined time, is subtracted from a filtered signal in a subtractor 24 to thereby obtain an error signal corresponding to the noise components. The error signal is again filtered by the median filter 25 and FIR filter 26. The filtered signal immediately becomes a source signal included in the noise component. This source signal and a source signal output from the FIR filter 22 and passed through the delay 27 are summed in an adder 28 to thereby obtain a final source signal  $s_k$ .

However, by the interlaced-to-progressive scanning converting method adopting such double-smoothing method in processing a picture signal, the picture signal tends to be excessively repressed and a stepped edge still remains due to the bias error of the edge portion generated in the median filter.

Meanwhile, an adaptive median filter system is disclosed in U.S. Patent No. 4,682,230 wherein the relative density of an impulse noise component included in an input signal is detected. Here, a control signal corresponding to the detected noise density is generated, and a signal sampled for a median-filtering is adaptively filtered according to the control signal.

It is an aim of preferred embodiments of the invention to provide an interlaced-to-progressive scanning converting apparatus having a double-smoothing function by which Gaussian noise and impulse noise can be effectively eliminated while picture contours are maintained.

It is another aim to provide an interlaced-to-progressive scanning converting method having a double-smoothing function.

According to a first aspect of the invention there is provided an interlaced-to-progressive scanning converting apparatus having a double smoothing function, wherein an interlaced scanning television signal is converted into a progressive scanning television signal, said apparatus comprising:

a double smoothing circuit for receiving an input interlaced scanning signal and performing a double smoothing function thereon;

interpolation signal generating means for generating a line delayed signal and interpolation scanning line signal from an output signal of said double smoothing circuit; and

means for generating a progressive scanning signal from the signal generated by said interpolation signal generating means.

Preferably, said double smoothing circuit (30) comprises:

first median-filtering means for median-filtering an input interlaced scanning signal;

first censoring means for receiving the median-filtered signal from said first median-filtering means and censoring it beyond a predetermined critical value; and

first order statistics filtering (OSF) means for receiving the signal censored by said first censoring means, setting a predetermined coefficient to the received signal and outputting the result.

Said apparatus preferably further comprises:

first delay means for delaying said input interlaced scanning signal for a predetermined time;

subtracting means for subtracting the output signal of said first OSF means from the output signal of said first delay means and then outputting an error signal;

means for double-smoothing the output signal from said subtracting means;

second delay means for delaying the output signal of said OSF means for a predetermined time; and

means for adding said double-smoothed signal to the output signal of said second delay means and then supplying the sum to said interpolation signal generating means.

Said critical value for censoring may be obtained by adding the output signal of said first median-filtering means to the standard deviation ( $\sigma$ ) of the noise distribution, alternatively/additionally, said critical value may be obtained from a level difference ( $h$ ) at an edge of input data.

The said double smoother preferably comprises:

second median filtering means for median-filtering the output signal from said subtracting means;

second censoring means for censoring the signal median-filtered by said second median-filtering means; and

second order-statistics-filtering means for order-statistics-filtering the signal censored by said second censoring means.

Said apparatus preferably further comprises noise detecting means for receiving said input interlaced scanning signal and thereby detecting the extent of the noise included in the input signal and then supplying the standard deviation ( $\sigma$ ) of the noise distribution to said censoring means.

Preferably, said apparatus further comprises switching means (SW) having a first input terminal to which said interlaced scanning signal is applied, a second input terminal to which the output signal of said double smoothing circuit is applied to and an output terminal which is connected to said interpolation signal generating means, the switching means (SW) being arranged to perform a switching operation according to the extent of the noise detected by said noise detecting means.

Preferably, said first OSF means sets a weighting coefficient as a constant value to then calculate a mean value if pixel data of an input censored signal is greater than or equal to a first predetermined number, passes a median value if pixel data of an input censored signal is less than or equal to a second predetermined number, and sets a plurality of weighting coefficients so as to be linear filtered if the number of pixel data of an input censored signal comes between first and second predetermined numbers.

The said interpolation signal generating means may comprise:

scanning line delay means for delaying the output signal of said double-smoothing circuit by one scanning line period;

field delay means for delaying the output signal of said scanning line delay means by one field period; and

median means for receiving each output signal of double-smoothing circuit, scanning line delay means and field delay means and thereby calculating a mean value thereof.

Said progressive scanning signal generating means preferably receives each output signal of said scanning line delay means and median means and then alternatively outputs two input signals at a double speed of the input signal.

According to a second aspect, an interlaced-to-progressive scanning converting apparatus having a double-smoothing function is provided, said apparatus comprising:

first filtering means for median-filtering an input interlaced scanning video signal, applying a weighting coefficient according to the degree to which the filtered signal exceeds a predetermined critical value and outputting the result;

delaying and subtracting means for delaying said interlaced scanning video signal and thereby subtracting the output signal of said first filtering means from the delayed signal;

second filtering means for median-filtering the output signal of said delaying and subtracting means, applying a weighting coefficient according to the degree to which the filtered signal exceeds a predetermined critical value and thereby outputting the result;

delaying and adding means for delaying the output signal of said first filtering means and adding the delayed signal to the output signal of said second filtering means;

interpolation signal generating means for generating a line delayed signal and an interpolation scanning line signal from the output signal of said delaying and adding means; and

means for generating a progressive scanning signal from the signal generated from said interpolation signal generating means.

Said apparatus preferably further comprises noise detecting means for receiving said input interlaced scanning signal and thereby detecting the extent of the noise included in the input signal and then supplying the standard deviation ( $\sigma$ ) of the noise varied according to the extent thereof to said first and second filtering means.

The apparatus may further comprise switching means (SW) having a first input terminal to which said interlaced scanning signal is applied, a second input terminal to which the output signal of said delay and adding means is applied, and an output terminal connected to said interpolation signal generating means, the switching means (SW) being arranged to perform a switching operation according to the extent of the noise detected by said noise detecting means.

According to a third aspect, there is provided an interlaced-to-progressive scanning converting method having a double-smoothing function wherein an interlaced scanning television signal is converted into a progressive scanning television signal, the method comprising the steps of:

median-filtering an input interlaced scanning signal (a median-filtering step);

censoring a signal beyond a predetermined critical value by receiving the signal median-filtered by said median-filtering step (a censoring step);

receiving the signal censored by said censoring step, setting a predetermined weighting coefficient to the received signal and then outputting the result (an order-statistic-filtering (an OSF) step);

generating a line delayed signal and an interpolation scanning line signal from the output signal of the OSF step (an interpolation signal generating step); and

generating a progressive scanning signal from the signal generated by said interpolation signal generating step (a progressive scanning signal generating step).

Said method preferably further comprises the steps of:

firstly delaying said input interlaced scanning signal for a predetermined time;  
 subtracting the output signal of said order statistics filtering (OSF) step from the output signal of said  
 first delaying step;

double-smoothing the output signal of said subtracting step;

secondly delaying the output signal of said OSF step for a predetermined time; and

summing said double-smoothed signal and the output signal of said second delaying step and then supplying the resultant sum to said interpolation signal generating step.

Said critical value may be obtained by adding the output signal of said median-filtering step to the standard deviation ( $\sigma$ ) of the noise mixed with said output signal, alternatively/additionally, said critical value may be obtained from the level difference (h) at the edge of input data.

Said double-smoothing step preferably comprises the steps of:

median-filtering said signal output by said subtracting step;

censoring the signal median-filtered by said median-filtering step; and

order statistics filtering (OSF) the signal censored by said censoring step.

Said interpolation signal generating step preferably comprises the steps of:

delaying the output signal of said OSF step by a predetermined scanning line period (a scanning line delaying step);

delaying the output signal of said scanning line delaying step by a predetermined field period (a field delaying step); and

receiving each output signal of said OSF step, scanning line delaying step and field delaying step, and then calculating the median value thereof (a median step).

Preferably, the method further comprises a noise detecting step for receiving said input interlaced scanning signal and thereby detecting the extent of the noise included in the input signal and then supplying the standard deviation value varied according to the extent thereof to said censoring step.

Said method preferably further comprises a selecting step for selecting said interlaced scanning signal or the output signal of said OSF step according to the extent of the noise detected in said noise detecting step and thereby outputting the selected signal to said scanning line interpolating step.

Preferably, in said OSF step, a weighting coefficient is set as a constant value to thereby calculate the mean value if the pixel data of the input censored signal is greater than or equal to a first predetermined number, a median value is passed if the pixel data of the input censored signal is less than or equal to a second predetermined number, and a plurality of weighting coefficients are set so as to be linear-filtered if the pixel data of the input censored signal comes between the first and second predetermined numbers.

Preferably, in said progressive scanning signal generating step, each output signal of said scanning line delaying step and median step is received, and thereby two input signals are alternatively output at a double speed of the input signal.

According to a fourth aspect, there is provided an interlaced-to-progressive scanning converting method having a double-smoothing function, said method comprising the steps of:

firstly median-filtering an input interlaced scanning video signal, applying a weighting coefficient according to the degree to which the filtered signal exceeds a predetermined critical value and outputting the result;

delaying said interlaced scanning video signal and thereby subtracting the output signal of said first filtering step from the delayed signal;

secondly median-filtering the output signal of said delaying and subtracting step, applying a weighting coefficient according to the degree to which the filtered signal exceeds a predetermined critical value and outputting the result;

delaying the output signal of said first filtering step and adding the delayed signal to the output signal of said second filtering step;

generating a line delayed signal and an interpolation scanning line signal from the output signal of said delaying and adding step; and

generating a progressive scanning signal from the signal generated in said interpolation signal generating step.

Preferably, said method further comprises a noise detecting step for receiving said input interlaced scanning signal, detecting the extent of the noise included in said input signal and supplying the standard deviation ( $\sigma$ ) of the noise varied according to the extent thereof to said first and second filtering steps.

Said method further preferably comprises a selecting step for selecting said interlaced scanning signal or the output signal of said delaying and adding step according to the extent of the noise detected in said noise detecting step.

For a better understanding of the invention, and to show how embodiments of the same may be carried

into effect, reference will now be made, by way of example, to the accompanying diagrammatic drawings, in which:

Figure 1 is a block diagram of a conventional interlaced-to-progressive scanning converting apparatus;

Figure 2 is a block diagram of a conventional double-smoothing apparatus;

5 Figure 3 is a block diagram of a first embodiment of the interlaced-to-progressive converting apparatus having a double-smoothing function;

Figure 4 depicts pixel points for illustrating median-filtering adopted for extracting space correlative information;

Figure 5 is a detailed block diagram for explaining the median filter shown in Figure 3;

10 Figure 6 is a schematic block diagram of second embodiment of the interlaced-to-progressive converting apparatus having a double-smoothing function; and

Figure 7 is a schematic block diagram of still another embodiment of the interlaced-to-progressive converting apparatus having a double-smoothing function.

The interlaced-to-progressive conversion is based on a three-point vertical median-filtering in order to reduce inter-line flickering and line crawling generated in interlaced data. The three points are the interlaced data processed by a double-smoothing function. The double-smoothing is based on an order statistics filtering (OSF) performed by censoring, to eliminate impulse and/or non-impulse noise while a signal edge is maintained.

20 Figure 3 is a block diagram of an embodiment of the interlaced-to-progressive converting apparatus having a double-smoothing function according to the present invention.

The embodiment of Figure 3 is largely composed of two blocks. One is a block for double-smoothing an interlaced scanning signal  $x_k$  having noise components to produce a smoothed interlace signal  $S_k$ , and the other is a block for interlaced-to-progressive scanning conversion of the smoothed interlaced signal  $s_k$ .

25 In a double-smoother 30, if a signal has a distinct edge component distinct, since the signal is collapsed by an impulse noise and linear filtering damages the signal edge, the edge of the median filter allows a bias error depending on noise power and the magnitude of the signal edge. In addition, the median filter cannot smooth non-impulse noise as well as the linear filter can. To eliminate this characteristic, a double-smoothing method is adopted using OSF accompanied by a censoring operation.

30 The output from the OSF is a linear combination of the order statistics in the censored data group. The reference point for censoring data is set as a median value within a window. The OSF provides a compromise between the median filter and motion average filter.

35 In an interlaced-to-progressive scanning converter 40, the input pixels for three-point vertical median-filtering are two pixels from a present field and one pixel from a previous field. Input pixels are disposed in adjacent vertical lines but are horizontally located at the same position. Three-point vertical median-filtering is an adaptive method that automatically switches between a motion-screen and a still-screen without complicated motion detection and edge detection, thereby reducing flickering.

First, a double smoother 30 will be described in detail.

The interlaced scanning signal  $x_k$  including noise can be indicated as the sum of source signal component  $s_k$  and noise component  $n_k$  as follows.

$$40 \quad x_k = s_k + n_k \quad (1)$$

In a median filter 31, the interlaced scanning signal  $x_k$  is median-filtered by the window  $w$  shown in Figure 4, thereby reducing the impulse noise component.

45 Figure 4 is a sample positional diagram used for extracting space correlative information, where  $i$  represents a vertical line number,  $j$  represents a pixel number of line  $i$ ,  $K$  represents a field number, and  $P$  represents an interpolated pixel.

Figure 5 is a detailed block diagram for the median-filter shown in Figure 3. The median filter is composed of two scanning line delays 1 and 2, four sample delays 3 to 6, and a five pixel sorter 7, and performs five-pixel median-filtering as shown in Figure 4.

50 Referring to Figure 5, the interlaced scanning signal  $x_k$  is delayed for the period of one sample by delay 3 and is output to sorter 7 as a sample F.

The interlaced scanning signal  $x_k$  is delayed by the scanning line delay 1 for the period of one line and delayed by delays 4 and 5 for the period of two samples, thereby being output to sorter 7 as a sample D. The output signal of the delay 4 is applied to sorter 7 as a sample A.

55 Also, the output signal of scanning line delay 1 is delayed by scanning line delay 2 for the period of one line, then passes through the delay 6 to thereby be delayed for the period of one sample, and is output to sorter 7 as a sample B.

In Figure 4, five pixels A, B, D, E and F being located within the window  $w$  of the present field  $K$  are supplied simultaneously to sorter 7 by scanning line delays 1 and 2 and sample delays 3, 4, 5 and 6. Then, sorter 7

sorts the input samples in the order according to data amplitude and outputs the median value.

A median filter, such as median filter 31 of Figure 3, effectively filters impulse noise but, with respect to non-impulse noise, cannot filter as effectively as a linear filter.

Therefore, a smoothing filter which is a combination of the censoring unit 32 and OSF 33 is adopted to the median-filtered signal. The output signal  $\bar{x}_k$  of median filter 31 becomes a reference point of censoring by censoring unit 32 and the reference point is required not to be outliers.

The value of  $\bar{x}_k + 3\sigma$  (where  $\sigma$  represents the standard deviation of the noise distribution) is used as the bias value of the censored data. Additionally, to prevent the case in which the samples belonging to the other level of the edge are used for censoring, another condition (c) for selecting the critical value for censoring is added to the censored data ( $\bar{x}_k$ ).

Thus, assuming that the censored data  $x_j$  is an element of  $L_c$ , i.e.,  $x_j \in L_c$ ,

$$L_c = \{x_j \mid \bar{x}_k - c \leq x_j \leq \bar{x}_k + c\} \quad (2)$$

where  $c$  equals  $\min\{3\sigma, h/2\}$ . Also,  $3\sigma$  is experimentally determined according to channel characteristics or can be any other value.

In order to prevent an edge portion from being included in such a bias value and smoothing process, the censoring process has another critical value  $h/2$ . Here,  $h$  represents edge height expressed as a level difference between edges.

Gaussian non-impulse noise components are mostly within  $3\sigma$ . Here, if  $h/2$  value is less than  $3\sigma$ , the  $h/2$  value is selected as a critical value, and if  $3\sigma$  is less than  $h/2$ ,  $3\sigma$  is selected as a critical value. Also, in the event that separate means for calculating  $\sigma$  are not provided, the  $h$  value can be set at the discretion of a system designer, e.g., to 30.

The signal censored in the above manner is supplied to OSF 33.

An embodiment of the OSF means can be found in a paper by Alan C. Vovik, Thomas S. Huang and David C. Munson entitled "A Generalization of Median-filtering using Linear Combinations of Order Statistics" in *IEEE Trans. on Acoustics, Speech and Signal Processing*, Vol.31, No.6 (December 1993), pp1342-1350.

OSF 33 is a filter for mainly eliminating Gaussian noise and the output thereof is as follows.

$$u_k = \sum_i \alpha_i x_i$$

... (3)

where  $x_i$  is less than or equal to  $x_j$  given that  $i$  is less than or equal to  $j$ , and  $\alpha_i$  is a weighting coefficient.

In this manner, the OSF aligns the censored pixel data in the order of amplitude, smooths out the noise components remaining after median-filtering, and removes the stepped edge generated by the interlaced-to-progressive conversion, by setting a predetermined weighting coefficient with respect to each pixel data.

If the weighting coefficients  $\alpha_i$  of the OSF are all "1's," the OSF obtains a median value. If only pixel data corresponding to the median value are weighted by a weighting coefficient of "1," the OSF operates as a median-filter. If only the largest pixel data is weighted as "1," the OSF becomes a maximum filter. If only the smallest pixel data is weighted as "1," the OSF becomes a minimum filter. If the weighting coefficient  $\alpha_i$  is differently set for each pixel data, the OSF becomes a linear low-pass filter.

The combination of the aforementioned filters can be embodied in OSF 33 according to the output of censoring unit 32. For example, in the case of a five-point window as shown in Figure 4, if four or five points are censored, the weighting coefficients are set as "1" and their mean value is obtained. If three are censored, the weighting coefficients are set as 1/4, 1/2 and 1/4, respectively, to then be filtered. If one or two are censored, the reference value, i.e., the median value is passed without being changed. OSF 33 can be replaced by a linear-weighted order statistics filter (LWOS filter) or a linear combination of weighted order statistics filter (LCWOS filter), each of which are similar to OSF 33 in characteristics.

Since smoothing based on order statistics filtering preceded by censoring is undesirable, double-smoothing is performed.

By a subtractor 30a, the signal  $u_k$  output from OSF 33 is subtracted from the original interlaced scanning signal  $x_k$  delayed in a delay 34 for time matching. The resultant error signal of the subtraction can be expressed by equation (5). That is, since

$$u_k = s_k \quad (4)$$

Then,

$$z_k = x_k - u_k = n_k \quad (5)$$

Here,  $s_k$  and  $n_k$  are estimates for signal and noise, respectively.

While the error signal  $z_k$  passes through a median filter 35, censoring unit 36 and OSF 37, signal compo-

nent is detected from the signal again from which noise component is removed primarily.

Thereafter, the detected signal  $v_k$  is primarily double-smoothed and then summed with the signal  $u_k$  delayed in a delay 38 for a predetermined time in an adder 30b, thereby finally obtaining a double-smoothed signal  $s_k$ . That is,

$$w_k = v_k + u_k = s_k \quad (6)$$

Next, the operation of interlaced-to-progressive converter 40 for three-point vertical median-filtering will be described with reference to Figure 4.

The pixel points A, B and C shown in Figure 4 are double-smoothed data. The points A, B and C are used in the interlaced-to-progressive scanning conversion mode.

In this manner, the double-smoothed interlaced scanning signal  $s_k$  obtains pixel values A, B and C shown in Figure 4 by means of a scanning line delay 41 and field delay 42, and the pixel value P to be interpolated is obtained as their median value. That is to say,

$$P = \text{med} \{A, B, C\}$$

Since the interpolation using the median value have a high spatial correlativity in a motion picture, data from pixels A and B has a high probability to be selected. Also, in a still picture, data from pixel C is liable to be selected. Therefore, the interpolation is performed selectively according to the motion.

Here, the pixels A, B and C are all double-smoothed data and the pixel data P to be interpolated is selected by a median unit 43 which is a three-pixel sorter.

Thereafter, a double speed output unit 44 scans the double-smoothed pixel B and the interpolated pixel P at a double speed and thereby outputs a picture signal  $y_k$  by a progressive scanning method.

Figure 6 is a schematic block diagram showing a further embodiment of an interlaced-to-progressive scanning converting apparatus having a double-smoothing function.

Referring to the embodiment of Figure 6, the interlaced-to-progressive scanning converting apparatus comprises a double smoother 30, an interlaced/progressive converter 40, which are the same as those shown in Figure 3, and a noise detector 50. The noise detector 50 measures noise from the input interlaced scanning signal  $x_k$ , and thereby obtains the standard deviation  $\sigma$  of the noise and supplies the value  $\sigma$  to the censoring units 32 and 36 of the double smoother 30.

Then, double smoother 30 adaptively varies the critical value for censoring by the value  $\sigma$  variable according to the noise extent of the input signal  $x_k$ .

This will be described in detail.

In the above equation (2), the simulation result shows that  $h$  does not vary the performance sensitively. Therefore, it is possible to set the value  $h$  as a given value in manufacturing. Also, since the area beyond  $3\sigma$  is statistically regarded as an abnormal state, where  $\sigma$  is the standard deviation of noise component, the basis of censoring is set as  $3\sigma$ . Here,  $\sigma$  corresponds exactly to Gaussian noise and is expressed in the following equation (7).

$$\sigma = \sqrt{1/n \sum (x - \mu)^2}$$

... (7)

Here, since  $x$  represents an input signal and  $\mu$  represents a mean value, it is much easier to calculate the value  $\sigma$  in a flat area. For example, it is possible to check the variation in the portion without a signal component in a vertical blanking period.

In other words, the calculation of equation (7), which involves finding the square root of a squared value, is complicated. More simply, the noise state can be estimated from the sum of a given period of the flat area and the value can be replaced by  $\sigma$ .

Assuming that the level of the flat portion is zero, it is possible to evaluate the noise amount quantitatively by an absolute value sum.

If the noise amount (absolute value sum) is large,  $\sigma$  is set to be large, and vice versa. Strictly speaking, since  $\sigma$  is an evaluation basis for the Gaussian noise, in order to demonstrate fully the characteristics of the present invention, it is desirable to calculate  $\sigma$  after the impulse noise is eliminated.

Figure 7 is a schematic block diagram of the interlaced-to-progressive scanning converting apparatus having a double-smoothing function according to still another embodiment of the present invention. When compared with the device shown Figure 6, the apparatus further includes a switch SW whose first input terminal is connected with the input terminal to which an interlaced-to-progressive signal is input, whose second input terminal is connected with the output of the double smoother 30, and whose output is connected with the input of the interlaced-to-progressive converter 40.

As shown in Figure 7, the switch SW selects either the input signal  $x_k$  or double-smoothed output signal

and supplies the selected signal to the interlaced-to-progressive converter 40. At this time, the switching operation of the switch SW is controlled according to the noise extent N detected by the noise detector 50. That is to say, if there is no noise in the input signal  $x_k$ , the double-smoothing with respect to the input signal is omitted and only the interlaced-to-progressive conversion is performed. If there is noise in the input signal  $x_k$ , the input signal  $x_k$  is double-smoothed in the double smoother 30 and then the interlaced-to-progressive conversion is performed.

The interlaced-to-progressive scanning converting apparatus according to the present invention is adopted for image apparatuses such as televisions, facsimiles or medical appliances.

As described above, the interlaced-to-progressive scanning converting apparatus having a double-smoothing function, and the method therefor, according to the present invention, can eliminate impulse noise and Gaussian noise effectively and can prevent the occurrence of a stepped edge phenomenon generated in an interlaced-to-progressive conversion, by performing double-smoothing composed of median-filtering, censoring and order statistics filtering with respect to an interlaced scanning signal and then converting it into a progressive scanning signal.

The reader's attention is directed to all papers and documents which are filed concurrently with or previous to this specification in connection with this application and which are open to public inspection with this specification, and the contents of all such papers and documents are incorporated herein by reference.

All of the features disclosed in this specification (including any accompanying claims, abstract and drawings), and/or all of the steps of any method or process so disclosed, may be combined in any combination, except combinations where at least some of such features and/or steps are mutually exclusive.

Each feature disclosed in this specification (including any accompanying claims, abstract and drawings), may be replaced by alternative features serving the same, equivalent or similar purpose, unless expressly stated otherwise. Thus, unless expressly stated otherwise, each feature disclosed is one example only of a generic series of equivalent or similar features.

The invention is not restricted to the details of the foregoing embodiment(s). The invention extends to any novel one, or any novel combination, of the features disclosed in this specification (including any accompanying claims, abstract and drawings), or to any novel one, or any novel combination, of the steps of any method or process so disclosed.

## Claims

1. An interlaced-to-progressive scanning converting apparatus having a double smoothing function, wherein an interlaced scanning television signal is converted into a progressive scanning television signal, said apparatus comprising:
  - a double smoothing circuit (30) for receiving an input interlaced scanning signal and performing a double smoothing function thereon;
  - interpolation signal generating means (40) for generating a line delayed signal and interpolation scanning line signal from an output signal of said double smoothing circuit; and
  - means (44) for generating a progressive scanning signal from the signal generated by said interpolation signal generating means (40).
2. Apparatus according to claim 1, wherein said double smoothing circuit (30) comprises:
  - first median-filtering means (31) for median-filtering an input interlaced scanning signal;
  - first censoring means (32) for receiving the median-filtered signal from said first median-filtering means (31) and censoring it beyond a predetermined critical value; and
  - first order statistics filtering (OSF) means (33) for receiving the signal censored by said first censoring means (32), setting a predetermined coefficient to the received signal and outputting the result.
3. Apparatus as claimed in claim 2, said apparatus further comprising:
  - first delay means (34) for delaying said input interlaced scanning signal for a predetermined time;
  - subtracting means for subtracting the output signal of said first OSF means (33) from the output signal of said first delay means (34) and then outputting an error signal;
  - means (35, 36, 38) for double-smoothing the output signal from said subtracting means;
  - second delay means (37) for delaying the output signal of said OSF means (33) for a predetermined time; and
  - means (30b) for adding said double-smoothed signal to the output signal of said second delay means (37) and then supplying the sum to said interpolation signal generating means (40).

4. Apparatus as claimed in claim 2 or 3, wherein said critical value for censoring is obtained by adding the output signal of said first median-filtering means (31) to the standard deviation ( $\sigma$ ) of the noise distribution.
5. Apparatus as claimed in any of claims 2 to 4, wherein said critical value for censoring is obtained from a level difference (h) at an edge of input data.
6. Apparatus as claimed in any of claims 3 to 5, wherein said double smoother comprises:
  - second median filtering means (35) for median-filtering the output signal from said subtracting means (30a);
  - second censoring means (36) for censoring the signal median-filtered by said second median-filtering means (35); and
  - second order-statistics-filtering means (38) for order-statistics-filtering the signal censored by said second censoring means (36).
7. Apparatus, as claimed in any of claims 2 to 6, said apparatus further comprising noise detecting means (50) for receiving said input interlaced scanning signal and thereby detecting the extent of the noise included in the input signal and then supplying the standard deviation ( $\sigma$ ) of the noise distribution to said censoring means (32, 36).
8. Apparatus as claimed in claim 7, said apparatus further comprising switching means (SW) having a first input terminal to which said interlaced scanning signal is applied, a second input terminal to which the output signal of said double smoothing circuit (30) is applied to and an output terminal which is connected to said interpolation signal generating means (40), the switching means (SW) being arranged to perform a switching operation according to the extent of the noise detected by said noise detecting means (50).
9. Apparatus as claimed in any of claims 2 to 8, wherein said first OSF means (33) sets a weighting coefficient as a constant value to then calculate a mean value if pixel data of an input censored signal is greater than or equal to a first predetermined number, passes a median value if pixel data of an input censored signal is less than or equal to a second predetermined number, and sets a plurality of weighting coefficients so as to be linear filtered if the number of pixel data of an input censored signal comes between first and second predetermined numbers.
10. Apparatus as claimed in any of the preceding claims, wherein said interpolation signal generating means (40) comprises:
  - scanning line delay means (41) for delaying the output signal of said double-smoothing circuit (30) by one scanning line period;
  - field delay means (42) for delaying the output signal of said scanning line delay means (41) by one field period; and
  - median means (43) for receiving each output signal of double-smoothing circuit (30), scanning line delay means (41) and field delay means (42) and thereby calculating a mean value thereof.
11. Apparatus as claimed in claim 10, wherein said progressive scanning signal generating means (44) receives each output signal of said scanning line delay means (41) and median means (43) and then alternatively outputs two input signals at a double speed of the input signal.
12. An interlaced-to-progressive scanning converting apparatus having a double-smoothing function, said apparatus comprising:
  - first filtering means (31, 32, 33) for median-filtering an input interlaced scanning video signal, applying a weighting coefficient according to the degree to which the filtered signal exceeds a predetermined critical value and outputting the result;
  - delaying and subtracting means (34, 30a) for delaying said interlaced scanning video signal and thereby subtracting the output signal of said first filtering means (31, 32, 33) from the delayed signal;
  - second filtering means (35, 36, 38) for median-filtering the output signal of said delaying and subtracting means (34, 30a), applying a weighting coefficient according to the degree to which the filtered signal exceeds a predetermined critical value and thereby outputting the result;
  - delaying and adding means (37, 30b) for delaying the output signal of said first filtering means (31, 32, 33) and adding the delayed signal to the output signal of said second filtering means (35, 36, 38);
  - interpolation signal generating means (40) for generating a line delayed signal and an interpolation

scanning line signal from the output signal of said delaying and adding means (30b); and  
means for generating a progressive scanning signal (44) from the signal generated from said interpolation signal generating means.

- 5 13. Apparatus as claimed in claim 12, said apparatus further comprising noise detecting means (50) for receiving said input interlaced scanning signal and thereby detecting the extent of the noise included in the input signal and then supplying the standard deviation ( $\sigma$ ) of the noise varied according to the extent thereof to said first (31, 32, 33) and second (35, 36, 38) filtering means.
- 10 14. Apparatus as claimed in claim 13, said apparatus further comprising switching means (SW) having a first input terminal to which said interlaced scanning signal is applied, a second input terminal to which the output signal of said delay and adding means (37, 30b) is applied, and an output terminal connected to said interpolation signal generating means (40), the switching means (SW) being arranged to perform a switching operation according to the extent of the noise detected by said noise detecting means (50).
- 15 15. An interlaced-to-progressive scanning converting method having a double-smoothing function wherein an interlaced scanning television signal is converted into a progressive scanning television signal, the method comprising the steps of:
  - median-filtering an input interlaced scanning signal (a median-filtering step);
  - 20 censoring a signal beyond a predetermined critical value by receiving the signal median-filtered by said median-filtering step (a censoring step);
  - receiving the signal censored by said censoring step, setting a predetermined weighting coefficient to the received signal and then outputting the result (an order-statistic-filtering (an OSF) step);
  - generating a line delayed signal and an interpolation scanning line signal from the output signal of the OSF step (an interpolation signal generating step); and
  - 25 generating a progressive scanning signal from the signal generated by said interpolation signal generating step (a progressive scanning signal generating step).
- 30 16. A method as claimed in claim 15, said method further comprising the steps of:
  - firstly delaying said input interlaced scanning signal for a predetermined time;
  - subtracting the output signal of said order statistics filtering (OSF) step from the output signal of said first delaying step;
  - double-smoothing the output signal of said subtracting step;
  - secondly delaying the output signal of said OSF step for a predetermined time; and
  - 35 summing said double-smoothed signal and the output signal of said second delaying step and then supplying the resultant sum to said interpolation signal generating step.
17. A method as claimed in claim 15 or 16, wherein said critical value is obtained by adding the output signal of said median-filtering step to the standard deviation ( $\sigma$ ) of the noise mixed with said output signal.
- 40 18. A method as claimed in claim 15, 16 or 17 wherein said critical value is obtained from the level difference (h) at the edge of input data.
19. A method as claimed in claim 16, or claims 17 or 18 as dependant upon claim 16, wherein said double-smoothing step comprises the steps of:
  - 45 median-filtering said signal output by said subtracting step;
  - censoring the signal median-filtered by said median-filtering step; and
  - order statistics filtering (OSF) the signal censored by said censoring step.
- 50 20. A method as claimed in any of claims 15 to 19, wherein said interpolation signal generating step comprises the steps of:
  - delaying the output signal of said OSF step by a predetermined scanning line period (a scanning line delaying step);
  - delaying the output signal of said scanning line delaying step by a predetermined field period (a field delaying step); and
  - 55 receiving each output signal of said OSF step, scanning line delaying step and field delaying step, and then calculating the median value thereof (a median step).
21. A method as claimed in any of claims 15 to 20, wherein the method further comprises a noise detecting

step for receiving said input interlaced scanning signal and thereby detecting the extent of the noise included in the input signal and then supplying the standard deviation value varied according to the extent thereof to said censoring step.

- 5     **22.** A method as claimed in claim 21, said method further comprising a selecting step for selecting said interlaced scanning signal or the output signal of said OSF step according to the extent of the noise detected in said noise detecting step and thereby outputting the selected signal to said scanning line interpolating step.
- 10    **23.** A method as claimed in any of claims 15 to 22 wherein, in said OSF step, a weighting coefficient is set as a constant value to thereby calculate the mean value if the pixel data of the input censored signal is greater than or equal to a first predetermined number, a median value is passed if the pixel data of the input censored signal is less than or equal to a second predetermined number, and a plurality of weighting coefficients are set so as to be linear-filtered if the pixel data of the input censored signal comes between  
15    the first and second predetermined numbers.
- 24.** A method as claimed in any of claims 15 to 23, wherein, in said progressive scanning signal generating step, each output signal of said scanning line delaying step and median step is received, and thereby two input signals are alternatively output at a double speed of the input signal.
- 20    **25.** An interlaced-to-progressive scanning converting method having a double-smoothing function, said method comprising the steps of:  
      firstly median-filtering an input interlaced scanning video signal, applying a weighting coefficient according to the degree to which the filtered signal exceeds a predetermined critical value and outputting the result;  
25       delaying said interlaced scanning video signal and thereby subtracting the output signal of said first filtering step from the delayed signal;  
      secondly median-filtering the output signal of said delaying and subtracting step, applying a weighting coefficient according to the degree to which the filtered signal exceeds a predetermined critical value and outputting the result;  
30       delaying the output signal of said first filtering step and adding the delayed signal to the output signal of said second filtering step;  
      generating a line delayed signal and an interpolation scanning line signal from the output signal of said delaying and adding step; and  
      generating a progressive scanning signal from the signal generated in said interpolation signal generating step.  
35    **26.** A method as claimed in claim 25, said method further comprising a noise detecting step for receiving said input interlaced scanning signal, detecting the extent of the noise included in said input signal and supplying the standard deviation ( $\sigma$ ) of the noise varied according to the extent thereof to said first and second filtering steps.  
40    **27.** A method as claimed in claim 25 or 26, said method further comprising a selecting step for selecting said interlaced scanning signal or the output signal of said delaying and adding step according to the extent of the noise detected in said noise detecting step.  
45

FIG. 1 (PRIOR ART)

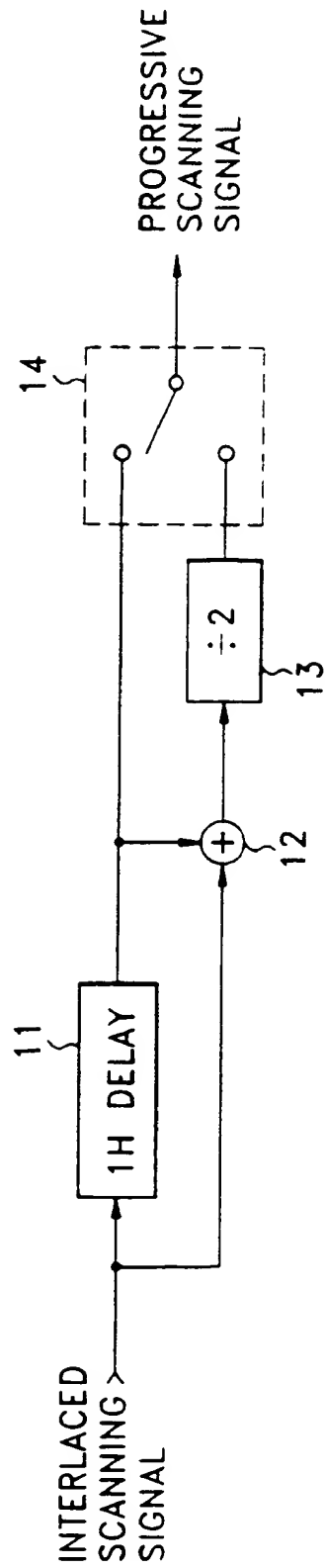


FIG. 2 (PRIOR ART)

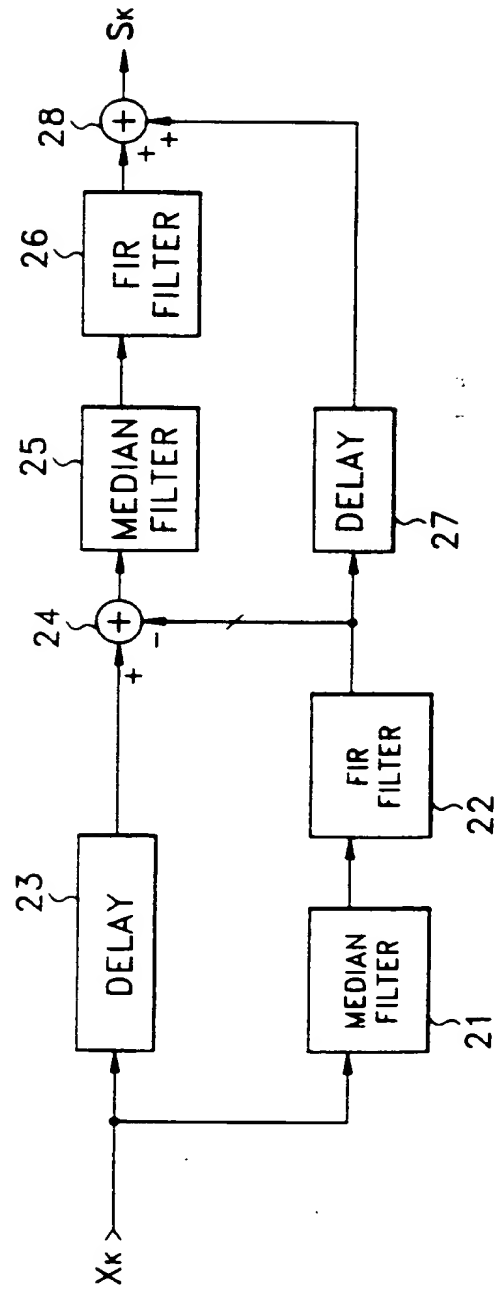


FIG. 3

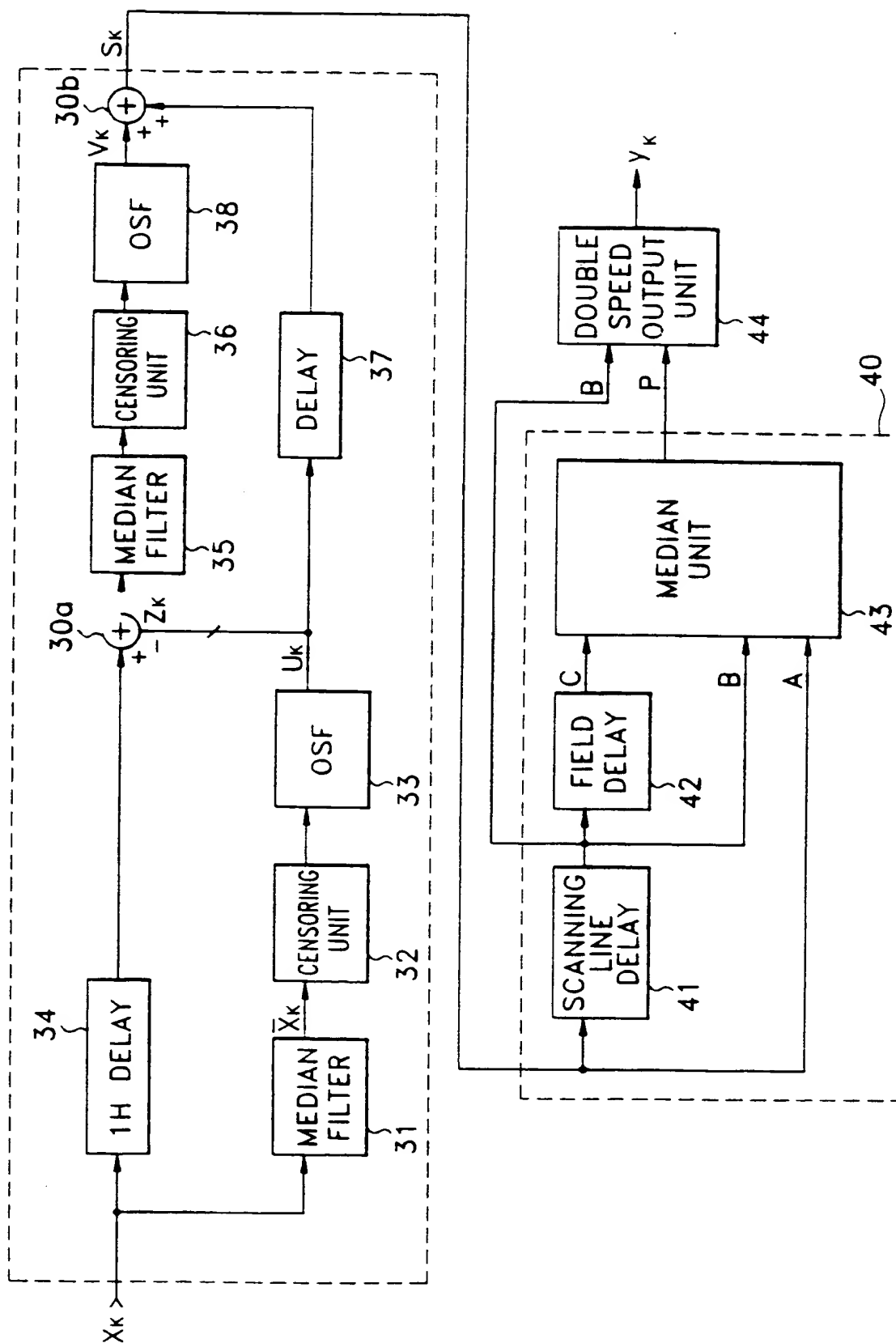


FIG. 4

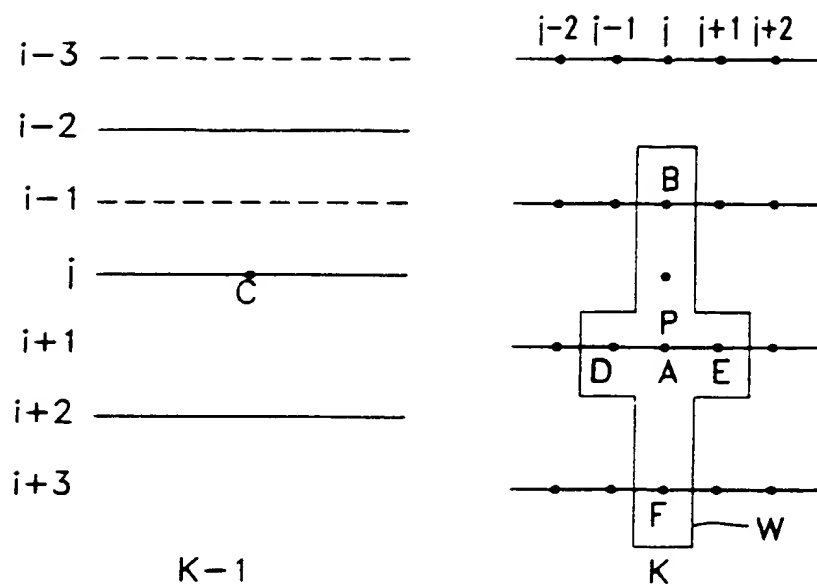


FIG. 5

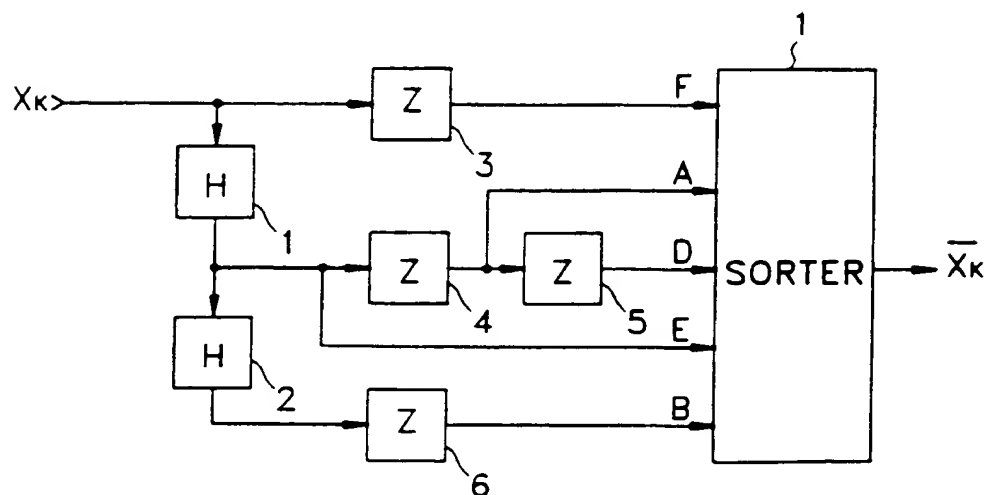


FIG. 6

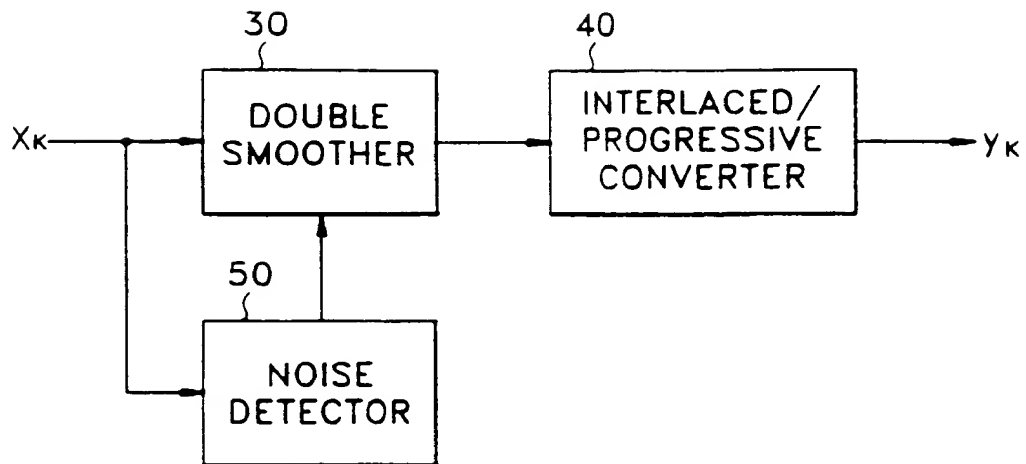
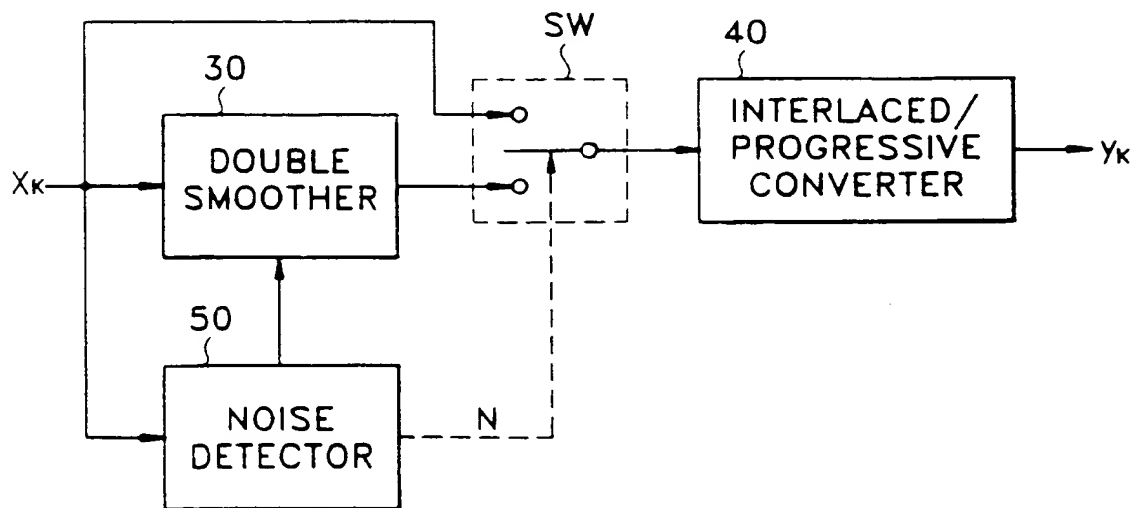


FIG. 7





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# EUROPEAN SEARCH REPORT

Application Number  
EP 94 30 3961

| DOCUMENTS CONSIDERED TO BE RELEVANT  |   |   |  |
|--|---|---|--|
| Category   | Citation of document with indication, where appropriate, of relevant passages   | Relevant to claim                                   | CLASSIFICATION OF THE APPLICATION (Int.Cl.5) |
| Y  | IEEE INTERNATIONAL SYMPOSIUM ON CIRCUITS AND SYSTEMS, vol.4/4, 3 May 1990, NEW ORLEANS (US) pages 3042 - 3045   | 1   | H04N5/44                                     |
| A  | JUHOLA J. ET AL. 'ON VLSI IMPLEMENTATION OF MEDIAN BASED FIELD RATE UP-CONVERSION' * the whole document *   | 10-12, 15, 24, 25                                   |  |
| D, Y   | IEEE TRANSACTIONS ON ACOUSTICS, SPEECH, AND SIGNAL PROCESSING, vol. ASSP-23, no. 6, December 1975 pages 552 - 557<br>LAWRENCE R. RABINER 'Applications of a Nonlinear Smoothing Algorithm to Speech Processing' | 1   |  |
| D, A   | * the whole document *  | 12, 15, 25  |  |
| A  | EP-A-0 187 540 (VICTOR COMPANY OF JAPAN, LTD.)<br>* abstract *<br>* page 3, line 23 - page 6, line 26; figures 1, 3-5 *   | 1, 12, 15, 25                                       |  |
| A  | AU-A-8 936 611 (UNISEARCH LTD.)<br>* page 2, line 1 - page 4, line 16 *<br>* page 22, line 1 - line 30; claims 1-4; figure 17 *   | 1, 2, 9, 15, 23                                     | TECHNICAL FIELDS SEARCHED (Int.Cl.5)<br>H04N |
| A  | EP-A-0 252 763 (VICTOR COMPANY OF JAPAN, LTD.)<br>* page 4, line 30 - line 47; figures 1A, 3A, 4, 15 *  | 1, 12, 15, 25                                       |  |
| The present search report has been drawn up for all claims   |   |   |  |
| Place of search<br>THE HAGUE   |   | Date of completion of the search<br>21 October 1994 | Examiner<br>Fuchs, P                         |
| <p><b>CATEGORY OF CITED DOCUMENTS</b></p> <p>X : particularly relevant if taken alone<br/> Y : particularly relevant if combined with another document of the same category<br/> A : technological background<br/> O : non-written disclosure<br/> P : intermediate document</p> <p>T : theory or principle underlying the invention<br/> E : earlier patent document, but published on, or after the filing date<br/> D : document cited in the application<br/> I : document cited for other reasons</p> <p>&amp; : member of the same patent family, corresponding document</p> |   |   |  |

EPO FORM 1503 (03.92) (P04C01)



European Patent  
Office

# EUROPEAN SEARCH REPORT

Application Number  
EP 94 30 3961

| DOCUMENTS CONSIDERED TO BE RELEVANT  |   |   |  |
|--|---|---|--|
| Category   | Citation of document with indication, where appropriate, of relevant passages   | Relevant to claim                                   | CLASSIFICATION OF THE APPLICATION (Int.Cl.5) |
| A  | EP-A-0 531 818 (SALORA OY)<br>* abstract *<br>* column 3, line 17 - line 34; figure 1A *  | 1, 10, 12, 15, 25                                   |  |
| D, A   | US-A-4 682 230 (PERLMAN ET AL.)<br>* column 1, line 55 - line 64 *<br>* column 2, line 111 - line 62; figure 1 *  | 1, 2, 7, 12, 13, 15, 21, 25, 26                     |  |
| D, A   | IEEE TRANSACTIONS ON ACOUSTICS, SPEECH, AND SIGNAL PROCESSING, vol. ASSP-31, no. 6, December 1983 pages 1342 - 1349<br>ALAN C. BOVIC 'A Generalization of Median Filtering Using Linear Combinations of Order Statistics'<br>* the whole document * | 1, 2, 9, 15, 23                                     |  |
|  |   |   | TECHNICAL FIELDS SEARCHED (Int.Cl.5)         |
| The present search report has been drawn up for all claims   |   |   |  |
| Place of search<br>THE HAGUE   |   | Date of completion of the search<br>21 October 1994 | Examiner<br>Fuchs, P                         |
| <p><b>CATEGORY OF CITED DOCUMENTS</b></p> <p>X : particularly relevant if taken alone<br/> Y : particularly relevant if combined with another document of the same category<br/> A : technological background<br/> O : non-written disclosure<br/> P : intermediate document</p> <p>T : theory or principle underlying the invention<br/> E : earlier patent document, but published on, or after the filing date<br/> D : document cited in the application<br/> L : document cited for other reasons<br/> &amp; : member of the same patent family, corresponding document</p> |   |   |  |

EPO FORM 150 (03.82) (P/MCOI)